

FISH OTOLITHS FROM THE BATHONIAN OF SOUTHERN ENGLAND

by F. C. STINTON and H. S. TORRENS

ABSTRACT. The occurrence of fish otoliths in the English Bathonian is recorded, some ten undescribed forms being represented. These are described together with details of the stratigraphy at the sections yielding them.

THE fragmentary skeletal and dental fish remains which occur sporadically in the English Middle Jurassic have appeared to indicate that true Fishes other than sharks, are rare in these strata. However, the discovery of numerous otoliths by one of us (H.S.T.) suggests that they were much commoner than was formerly supposed although limited in the number of species. The otoliths were obtained (by H.S.T.) during the compilation of the stratigraphical data which follows. The relationship of the otoliths to other skeletal remains is obscure as none have been demonstrated *in situ* in skulls in this country.

STRATIGRAPHY (H. S. T.)

The two Bathonian localities at which otoliths were found are exposed respectively in Wiltshire and in Dorset. The stage name 'Bathonian' is used in the sense recommended by the Jurassic Colloquium held in Luxembourg in 1962 (published 1964, p. 78).

The first locality is the well-known section beside the eastern bank of the Kennet and Avon canal, Bradford on Avon (Nat. Grid ST 826600) described by Cox (1941, 33) among others. The actual succession at this pit has never appeared in print and the following section is reproduced, somewhat modified, by kind permission of Dr. C. E. Periam, from his unpublished Ph.D. thesis (1956, p. 32):

Descending section measured at the eastern end of the clay pit:

	ft.	ins.
FOREST MARBLE		
h. Grey-brown clay passing into clay soil		6
g. Shelly limestone		6
f. Grey clay	8	0
e. Shelly flaggy limestones separated by a 6-in. clay band	2	0
BRADFORD CLAY		
d. Grey clay	2	0
c. Impersistent fine-grained platy, shelly limestone full of fossil wood in places, <i>Clydoniceras in situ</i>	1	0
b. Grey clay	9	0
GREAT OOLITE		
a. Floor of hard shelly, oolitic limestone with adherent oysters etc.		seen

Bed *a* shows the topmost surface of the Great Oolite limestone while beds *b*, *c*, *d* together comprise the Bradford Clay—some 12 ft. thick. It is not often possible to draw

a sharp boundary between the Bradford Clay and the Forest Marble but bed *e* is probably best referred to the Forest Marble.

The Bradford Clay was assigned by Arkell (1959, p. 237) to the *Hollandi* zone of the Upper Bathonian but it is best (Torrens 1965, p. 49) to follow Tintant (1963, p. 55) in regarding this 'zone' as a subzone of the *Discus* zone. Bed *c* at this locality yielded a specimen of *Clydoniceras in situ* (H. S. Torrens coll. 997). This is only the third ammonite (all *Clydoniceras*) so far recorded from the Bradford Clay.

The rich fauna of the Bradford Clay (see Cunnington 1860 and Periam 1956, p. 33, locality 40) is best collected from the base of bed *b*. Periam noted the same assemblage to occur at the top of bed *c* as well. This was due to his failure to recognize the existence of a small fault, first pointed out by Dr. G. Green of the Geological Survey, which causes the Great Oolite Limestone (bed *a*) to form a second higher platform in the western part of the pit, nearest to the canal. This second platform on which the basal highly fossiliferous Bradford Clay is bedded, corresponds at first glance with the higher bed *c* and caused Periam to record the Bradford Clay fauna at two horizons i.e. on the top of beds *a* and *c*. In fact, the apparent recurrence of the same fauna at two different horizons is due to repetition by this fault. There may also be some horizontal displacement between the sections on either side of the fault.

The otoliths were obtained by washing the clayey oolite-rich marl collected *in situ* at the base of bed *b* through a sieve (mesh 20) and handpicking the residue under a lens. They occurred only infrequently here, approximately one specimen being obtained from every 2 lb. of original sample.

A much larger fish otolith fauna was collected from the 3–4 ft. of blue-grey clay immediately underlying the *Ostrea (Liostrea) hebridica* Forbes lumachelle exposed at Rodden Hive Point, south-west of Langton Herring, Dorset (SY 569823). This locality is recorded in the *Directory of British Fossiliferous Localities* (1954, p. 25) and the horizon, together with its fauna, has been fully described by Arkell (1940, pp. 42–9; 1947, pp. 17–18).

The otoliths were obtained by the method detailed above and are extraordinarily abundant here, a pound of clay yielding as many as five otoliths. Many of the specimens are encrusted with microfaunal bryozoa and serpulids, suggesting that the deposition of these clays was extremely slow. Macrofossils, especially the ammonites and Trigoniac, are similarly encrusted with large serpulids and must have lain on the sea-floor for a considerable period before burial.

Arkell (1959, p. 239) assigned this horizon to a level above the *Wattonensis* beds of Dorset. Further investigation of the relevant faunas confirms the suggestion of House (1957, p. 69) that it can be more accurately correlated with the upper part of the *Wattonensis* beds themselves.

An interesting brachiopod, *Acanthothiris powerstockensis* Buckman and Walker, occurs rarely at this exposure. It has not previously been recorded here but its presence, together with *Rugitela*, at the same horizon, indicates that the fauna here may be somewhat condensed in relation to that of the type locality at Watton Cliff, Dorset, where the two genera occupy different beds (Muir-Wood 1936, p. 22).

The zonal affinities of this horizon are controversial but it can be placed in an intermediate zone between the *Aspidoides* and *Morrisi* zones, at the base of the Upper Bathonian, for which no entirely suitable zonal index can yet be proposed. This is the unnamed zone of Torrens (1965, p. 50).

THE OTOLITHS (F. C. S.)

The determination of mesozoic otoliths presents problems not encountered with Tertiary forms which may be compared directly with those of living teleosts. The situation is further complicated by the fact that, with the exception of one entire specimen of the fish *Lycoptera middendorfi* Müller, from the NW. German Dogger, no otoliths have been demonstrated *in situ* in the skulls of whole fishes so far discovered. Furthermore these *in situ* otoliths, being lagenoliths (asterisci), are valueless in the present circumstances for the suite under investigation are all sacculiths (sagittae) apart from one possible utriculith (lapillus).

The circular or subcircular type of sacculith in Recent teleosts is always found in deep-bodied, compressed, circular fishes although, conversely, this type of fish does not necessarily possess a round sacculith. Thus one may look to fishes of similar morphology which occur in the Bathonian for it may be that the contours of the skulls regulate the shapes of the otoliths in some cases. It must be noted, however, that the very circular chaetodonts have quite dissimilar percoid sacculiths although those of the majority of other round fishes conform to the usual pattern.

A number of morphologically similar Jurassic fish genera occur in the Bathonian as well as the Lias and Kimmeridgian. They are included in the Semionotidae and Pycnodontidae but those with the former order are virtually excluded, for the modern *Lepiosteus* Lacépède, is presumed to have evolved from the Semionotidae. The sacculiths of *Lepiosteus* are quite insignificant while the utriculith is the major otolith so that these circular sacculiths could not be related to the semionotids. In any case, it is probable that those forms described as *incertae sedis curvatus* Frost (1926, p. 85, pl. 4, fig. 14) and as Lapilli types A & B Schröder (1956, p. 150, pl. 7, figs. 41–46) originate from semionotid skulls for they show much similarity to utriculiths of *Lepiosteus*.

With the elimination of the semionotids one is left with the pycnodonts and it is proposed to refer these otoliths to this group of fishes. There is no evidence to indicate which of the known Bathonian pycnodonts might have furnished these specimens so it is proposed to establish a new genus to embrace them.

Pokorny (1965, p. 384) has quoted Weiler as saying that modern teleosts are derived from a small group of related ganoids but these otoliths indicate an independent ancestry for a number of modern teleost groups whose otoliths have similar characters to these fossil forms. There is little or no supporting evidence, osteologically, but it might well be that evolutionary changes have obscured their relationship.

The commonest otoliths from these strata exhibit morphological features consistent with some of those seen among modern clupeids and, for this reason these are referred to the Leptolepidae for *Leptolepis* s.s. may well be the precursor of the true clupeids while *Pholidophorus* is possibly ancestral to the elopine fishes. Until recent times this group have been considered to be teleosts and Frost (1924) referred his otolith species of *Leptolepidarum* from the Upper Kimmeridgian to the Teleostei, remarking 'This earliest form yet described of a teleostean pointed saccular otolith . . .' when discussing the affinity of his species *Otolithus (Leptolepidarum) simplex*. Saint-Seine (1949) placed *Elops* in the Halecostomi and this arrangement was supported by Nybelin (1957) who considered *Elops* to be as much an holostean as *Annia* or *Lepiosteus*. Gosline (1960, p. 356) retained *Elops* in the Clupeiformes, remarking on the controversial structure of

the group, for all have certain characters relating them to the isospondylous fishes to a greater or lesser degree.

The present Systematics follow Saint-Seine in placing the Leptolepidae in the subclass Holostei, Division Halecostomes, the pholidophorids being separated at ordinal level. However, although these elopine otoliths almost certainly derive from *Pholidophorus* and *Leptolepis*, thus placing them among the Halecostomes in the present system, it must be realized that their obvious clupeoid characters prove them to be the parent stock for this group.

A forerunner of the engraulids may also be represented and a new genus, *Archengraulis* is proposed to embrace those otoliths which show some resemblance to those of *Engraulis* Cuvier.

Finally, this suite may include an ancestral form of the salmonoids but evidence is insufficient to be dogmatic on this point.

SYSTEMATIC DESCRIPTIONS

Superclass PISCES

Class ACTINOPTERYGII

Subclass CHONDROSTEI

Order CHONDROSTEIFORMES

Family CHONDROSTEIDAE

Genus GYROSTEUS (Agassiz) Egerton 1858, p. 883

Type species. *Gyrosteus mirabilis* Agassiz.

Gyrosteus subdeltoideus sp. nov.

Text-fig. 1a, b

Holotype. BM P47394. Bradford on Avon.

Paratypes and localities. Bradford on Avon, Leicester University Museum, 22725 (6 specimens).

Dimensions of holotype. Length 3.25 mm. Width 2.48 mm.

Description. A roughly triangular, left sacculith which is truncated dorsally. Dorsal rim short, horizontal, crenulate; posterior rim rounded, slightly crenulate; ventral rim long and rounded; anterior rim long and diagonal. Outer face smooth, nearly flat, with indistinct radial ribs from the dorsal area to the ventral rim. Inner face nearly flat, with a slightly arcuate sulcus opening widely on the anterior rim and narrowly on the posterior rim. It is set somewhat above the mid-line of the otolith. The sulcus consists of a very short, wide ostium, rather triangular in shape, with a long, somewhat concave lower rim with a downward trend. A long, narrower, slightly shallower cauda with parallel sides. Crista superior undivided and recurving at the ostial junction to coalesce with the upper part of the anterior rim. A very slight obtuse lower angle at the junction of ostium and cauda. A shallow depression above the crista superior, accentuating it. A moderate rostrum and excisura present but no antirostrum or colliculi. A rather wide, smooth, semicircular lower area present.

This otolith has a distinct affinity with those of the living *Acipenser* Linnaeus, both in

outline, sulcus characteristics and the features of the outer face, despite the slight amount of erosion from which it has suffered. The only relative in Jurassic times is *Gyrosteus* Agassiz, represented by skeletal remains named *G. mirabilis* Agassiz, which closely resembles the modern *Acipenser* and is recorded from the Upper Lias. It is possible that this fish had an extended range into the higher strata and this otolith is referred to this genus.

Subclass HOLOSTEI
(Division Holosteans)
Order PYCNODONTIFORMES
Family PYCNODONTIDAE
Genus SPHAERONCHUS gen. nov.

Type species. Sphaeronchus dorsetensis sp. nov.

Sacculiths with short, horizontal dorsal rims; rounded posterior rims which are continuous with the rounded ventral rims; oblique anterior rims which are slightly to moderately notched. Outer faces smooth and slightly convex. Convex inner faces with an arcuate sulcus opening widely on the anterior rim and just touching the posterior rim. Sulcus consisting of a somewhat semicircular, obliquely placed, deep, short ostium and a straight or slightly arcuate parallel-sided cauda which just reaches the posterior rim. Moderate rostrum and excisura but no antirostrum or colliculi. Osteological characters unknown.

Sphaeronchus dorsetensis sp. nov.

Text-fig. 2a, b

Holotype. BM P47395. Rodden Hive Point.

Paratypes and localities. Rodden Hive Point. Leicester University Museum 22718 (8 specimens). Bradford on Avon. Leicester University Museum 22727 (47 specimens).

Dimensions of holotype. Length 5.00 mm. Width 4.76 mm.

Description. A somewhat eroded, roughly circular, right sacculith. Dorsal rim short, horizontal, crenulate; posterior rim short, rounded, continuous with the rather deep, regularly rounded ventral rim; anterior rim obtuse and moderately notched. Outer face smooth, slightly convex. Inner face convex with an arcuate sulcus opening widely on the anterior rim and just touching the posterior rim. Sulcus consisting of a short, wide, deep, somewhat semicircular, obliquely placed ostium and a moderately wide, long, arcuate cauda which tapers towards the posterior rim. A rounded, lower right-angle and a slightly rounded upper angle are present at the junction of ostium and cauda. A depression above the crista superior, accentuating it. The sulcus is set a little above the mid-line and there is a wide, smooth, semicircular lower area. A moderate rostrum and excisura present but no antirostrum or collicula.

Pycnodont teeth referred to the genus *Gyronchus* Agassiz, occur in the Bathonian and it may be that these are congeneric with these otoliths.

Sphaeronchus circularis sp. nov.

Text-figs. 3a, b; 4

Holotype. BM P47396 (text-fig. 3a, b). Rodden Hive Point.*Paratypes and localities*. Rodden Hive Point. BM P47397 (text-fig. 4) and Leicester University Museum 22719 (111 specimens).*Dimensions of holotype*. Length 2.71 mm. Width 1.98 mm.

Description. An almost circular right sacculith, pointed anteriorly. Dorsal rim short, nearly horizontal, crenulate; posterior rim short, nearly vertical and continuous with the rather deeply rounded ventral rim; anterior rim oblique. Outer face smooth, convex, with an indistinct central umbo. Inner face slightly convex with a horizontal sulcus set slightly above the mid-line, opening obliquely on the anterior rim and terminating immediately adjacent to the posterior rim. Sulcus consisting of a short, rather deep ostium which is somewhat spatulate, and a narrower, slightly sinuous cauda which tapers to a point posteriorly. Crista superior recurving at the ostial end to form an acute angle and coalescing with the dorsal rim. A depression below the crista inferior accentuating it, while there is an obtuse lower angle at the junction of ostium and cauda. A moderate rostrum and excisura present but no anti-rostrum or collicula. Text-fig. 4 (BM P47397) represents a left sacculith.

This otolith generally resembles that of *Sphaeronchus dorsetensis* sp. nov., but differs in the sinuous cauda and the relatively shallower ventral area.

(Division Halecostomes)

Order PHOLIDIFORMES

Family PHOLIDOPHORIDAE

Genus PHOLIDOPHORUS Agassiz 1832, p. 145

Type Species. *Pholidophorus bechei* Agassiz.*Pholidophorus paradoxicus* sp. nov.

Text-fig. 5a, b

Holotype. BM P47401. Rodden Hive Point.*Paratypes and locality*. Rodden Hive Point. Leicester University Museum 22723 (6 specimens).*Dimensions of holotype*. Length 2.40 mm. Width 1.56 mm.

Description. An ovate, thin right sacculith, pointed anteriorly. Dorsal rim horizontal, coarsely denticulate; posterior rim nearly vertical, crenulate; ventral rim rounded, crenulate; anterior rim oblique, obtuse-angled. Slightly concave outer face with three small tuberculations on the dorsal periphery and radial ribbing traversing the otolith laterally to the ventral rim. Slightly convex inner face with a median sulcus opening obliquely on the anterior rim and terminating adjacent to the postero-ventral corner of the otolith. Sulcus consisting of a moderately deep, somewhat semicircular, obliquely placed ostium and a long, narrower cauda which curves downwards slightly as it approaches the posterior rim. Crista superior undivided and recurving at the ostial end

to coalesce with the dorsal rim. A moderate, obtuse lower angle at the junction of ostium and cauda. Both crista superior and crista inferior slightly accentuated by depressions above and below them respectively. A marked rostrum and moderate excisura present but no antirostrum or collicula.

This otolith is elopine in character and may perhaps be from a precursor of *Megalops* Lacépède, for the species of *Pholidophorus* represented by remains of entire fishes show a distinct resemblance to this genus.

Pholidophorus prae-elops sp. nov.

Text-figs. 6a, b; 7a, b

Holotype. BM P47402 (text-fig. 6a, b). Rodden Hive Point.

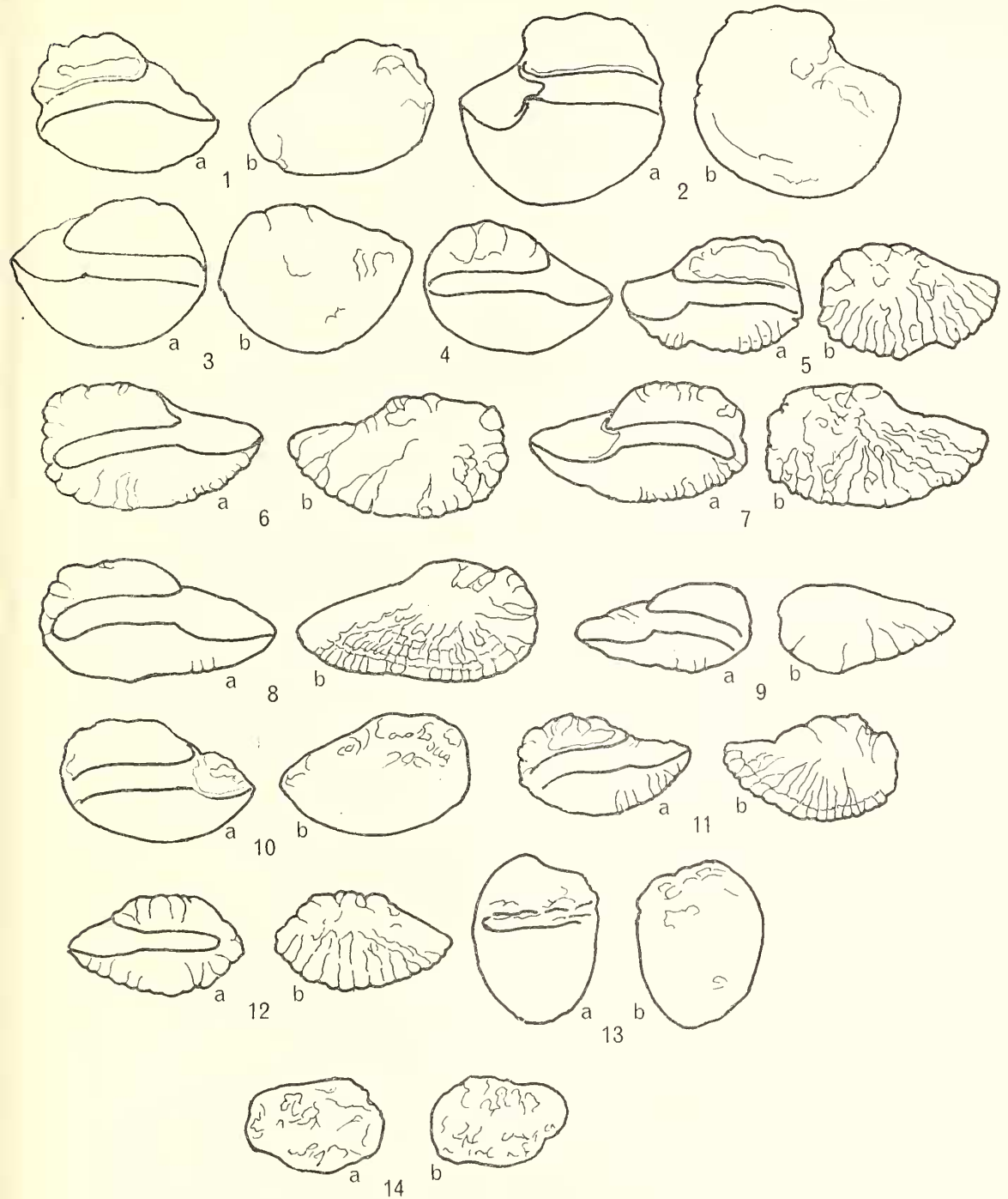
Paratypes and localities. Rodden Hive Point. BM P47403 (text-fig. 7a, b) and Leicester University Museum 22722 (20 specimens). Bradford on Avon. Leicester University Museum, 22726.

Dimensions of holotype. Length 5.01 mm. Width 2.27 mm.

Description. Slightly biconvex left sacculith, truncated posteriorly and pointed anteriorly. Dorsal rim horizontal, faintly crenulate; posterior rim short, vertical, faintly crenulate; ventral rim long, rounded, faintly crenulate; anterior rim oblique with an angulated notch. Outer face ornamented with transverse irregular ridges which radiate from the dorsal periphery to the ventral periphery. Inner face slightly convex with a median sulcus opening obliquely on the anterior rim and extending to the posterior rim. Sulcus consisting of a short, moderately deep, deltoid ostium which has a concave lower rim and a long, rather wide cauda curving slightly downwards near its posterior end which is open. Crista superior undivided and accentuated by a shallow depression above it. An obtuse lower angle present at the junction of ostium and cauda, prominent rostrum and excisura but no antirostrum or collicula.

These otoliths show a similarity to those of existing Elopidae and it seems very likely that they represent the precursors of this family.

TEXT-FIGS. 1-14. All of the figured specimens are contained in the collections of the British Museum (Natural History), Department of Palaeontology, and bear the registration numbers of this Institution. 1a, b. *Gyrosteus subdeltoideus* sp. nov. Holotype P47394. Left sacculith, inner and outer faces. $\times 10$. 2a, b. *Sphaeronchus dorsetensis* sp. nov. Holotype P47395. Right sacculith, inner and outer faces. $\times 8$. 3a, b. *Sphaeronchus circularis* sp. nov. Holotype P47396. Right sacculith, inner and outer faces. $\times 14$. 4. *Sphaeronchus circularis* sp. nov. P47397. Left sacculith, inner face. $\times 14$. 5a, b. *Pholidophorus paradoxicus* sp. nov. Holotype P47401. Right sacculith, inner and outer faces. $\times 15$. 6a, b. *Pholidophorus prae-elops* sp. nov. Holotype P47402. Left sacculith, inner and outer faces. $\times 8$. 7a, b. *Pholidophorus prae-elops* sp. nov. P47403. Right sacculith, inner and outer faces. $\times 10$. 8a, b. *Leptolepis tenuirostris* sp. nov. Holotype P47398. Left sacculith, inner and outer faces. $\times 10$. 9a, b. *Leptolepis tenuirostris* sp. nov. P47399. Right sacculith, inner and outer faces. $\times 10$. 10a, b. *Leptolepis densus* sp. nov. Holotype P47400. Left sacculith, inner and outer faces. $\times 10$. 11a, b. *Leptolepis roddenensis* sp. nov. Holotype P47405. Left sacculith, inner and outer faces. $\times 12$. 12a, b. *Archengranlis productus* sp. nov. Holotype P47404. Right sacculith, inner and outer faces. $\times 14$. 13a, b. *Cleidogonia antiqua* sp. nov. Holotype P47406. Left sacculith, inner and outer faces. $\times 18$. 14a, b. ? Utriculith. sp. indeterminate. P47800. Inner and outer faces. $\times 16$.



TEXT-FIGS. 1-14.

Order LEPTOLEPIDIFORMES
Family LEPTOLEPIDAE
Genus LEPTOLEPIS Agassiz 1832, p. 146

Type species. Leptolepis coryphaenoides (Bronn).

Leptolepis tenuirostris sp. nov.

Text-figs. 8a, b; 9a, b

Holotype. BM P47398 (text-fig. 8a, b). Rodden Hive Point.

Paratypes and locality. Rodden Hive Point BM P47399 (text-fig. 9a, b) and Leicester University Museum 22720 (147 specimens).

Dimensions of holotype. Length 4.60 mm. Width 2.31 mm.

Description. Relatively elongate, thin left sacculith, prominently pointed anteriorly and rounded posteriorly. Dorsal rim short, slightly concave; posterior rim rounded, crenulate; ventral rim long, horizontal, finely denticulate; anterior rim oblique, long and slightly sinuous. Outer face convex with a slight central umbo and radiating ribs on the ventral, dorsal and posterior areas. Indistinct concentric grooves surround the umbo on the ventral area. Inner face slightly convex with a median sulcus opening widely on the anterior rim and terminating very near to the posterior rim. Sulcus consisting of a wide, obliquely placed, short, semicircular ostium of moderate depth and a rather wide, somewhat shallower, long cauda which curves somewhat towards the posterior end. The crista superior recurves sharply to form an acute angle at the junction of ostium and cauda and there is also a moderate lower angle. A depression above the crista superior accentuating it. Marked rostrum and excisura but no antirostrum or collicula.

These otoliths almost certainly represent precursors of the modern clupeoids and their abundance in these beds may, perhaps, indicate that these fishes were gregarious by nature, as in the modern herrings. The outline and characters of the outer face are typically clupeoid while the sulcus is also rather similar although the cauda has not developed the characteristically greater width seen in the Recent forms.

Leptolepis densus sp. nov.

Text-fig. 10a, b

Holotype. BM P47400. Rodden Hive Point.

Paratypes and locality. Bradford on Avon. Leicester University Museum (3 specimens).

Dimensions of holotype. Length 3.63 mm. Width 2.17 mm.

Description. A rather thick, left sacculith. Dorsal rim horizontal, slightly undulant by virtue of two feeble lobes; nearly vertical, slightly rounded posterior rim; ventral rim rounded; anterior rim oblique and slightly undulant. Outer face smooth and slightly convex. Inner face smooth, almost flat with a median sulcus opening widely on the anterior rim and just touching the posterior rim. Sulcus consisting of a rather wide, short, deltoid ostium and a long, rather wide cauda which is open at its posterior

extremity. Crista superior recurving at its anterior end, forming an acute angle and coalescing with the anterior rim. A prominent lower angle present at junction of ostium and cauda. Crista superior accentuated by a shallow depression above it. A rostrum and excisura present but no antirostrum or collicula.

This otolith, although included here among the *Leptolepidae*, differs in being much thicker than those of the other species and its outline is more rounded. It shows some affinity with otoliths of the living *Gonorhynchus* Gronow, and also, in some degree, to the salmonoid fishes, in the characters of the sulcus.

Leptolepis roddenensis sp. nov.

Text-fig. 11a, b

Holotype. BM P47405. Rodden Hive Point.

Paratypes and locality. Rodden Hive Point. Leicester University Museum 22724 (8 specimens).

Dimensions of holotype. Length 2.68 mm. Width 1.56 mm.

Description. A thin, rather elliptical left sacculith which is pointed anteriorly. Dorsal rim irregularly denticulate, horizontal; posterior rim vertical, slightly crenulate; ventral rim rounded, finely denticulate; anterior rim oblique, slightly obtuse-angled. Outer face nearly flat with a row of indistinct, small tuberculations on the dorsal periphery and faint radial ribbing to the ventral rim. Slightly convex inner face with a median sulcus opening almost horizontally on the anterior rim and terminating adjacent to the postero-dorsal corner of the otolith. Sulcus consisting of a rather deltoid ostium with a concave lower rim and a long, slightly narrower, moderately deep cauda which is horizontal throughout its length but curving slightly downwards immediately before its posterior end which is open. Crista superior sinuous, undivided and accentuated by a depression above it. A slight, rounded, obtuse lower angle at the junction of ostium and cauda. Prominent rostrum and moderate excisura but no antirostrum or collicula. Smooth, semicircular lower area which is keeled at the ventral periphery.

This otolith differs from other described species of *Leptolepis* in its more horizontal anterior rim and straight, open-ended cauda.

Genus *ARCHENGRAULIS* nov. gen.

Elliptical sacculiths, pointed anteriorly and bluntly pointed posteriorly; irregularly crenulated dorsal, posterior and, ventral rims. Slightly convex outer face with irregular dorsal umbo and radial ribs to the ventral periphery, the posterior ones being tuberculate. Slightly convex inner face with a median sulcus opening obliquely on the anterior rim and terminating near the postero-ventral corner. Sulcus consisting of a short, rather deltoid, shallow, wide ostium and a long, rather wide, straight cauda. The crista superior is undivided, accentuated by a depression above it and, at its ostial end, recurving to coalesce with the dorsal rim. Marked rostrum and excisura. Osteological characters unknown.

Type species. *Archengraulis productus* sp. nov.

Archengraulis productus sp. nov.

Text-fig. 12a, b

Holotype. BM P47404. Rodden Hive Point.*Paratypes and locality*. Rodden Hive Point. Leicester University Museum 22721 (2 specimens).*Dimensions of holotype*. Length 2.48 mm. Width 1.38 mm.

Description. An elliptical right sacculith with the features described for the genotype. Dorsal rim slightly rounded and crenulate; posterior rim oblique, short, crenulate; ventral rim long, rounded, finely denticulate; anterior rim oblique, slightly concave. There is a very slight, rounded, obtuse lower angle at the junction of ostium and cauda. No antirostrum or collicula.

The produced posterior end of this otolith and its straight cauda distinguish it from other otoliths of the Leptolepidae and there is a similarity to otoliths of modern engraulids in several of its features.

Subclass TELEOSTEI

Superorder ACANTHOPTERYGII

Order BERYCIFORMES

Suborder ? BERYCOIDEI

Genus CLEIDOGONIA gen. nov.

Type species. *Cleidogonia antiqua* sp. nov.

Sacculiths very short, high, and elliptical in outline. Sulcus a little above the mid-line consisting of a relatively wide ostium and an horizontal cauda. The features suggest affinities with berycoid otoliths and this genus is tentatively referred to the Berycoidei. Osteological characters of genus unknown.

Cleidogonia antiqua sp. nov.

Text-fig. 13a, b

Holotype. BM P47406. Bradford on Avon.*Dimensions of holotype*. Length 1.30 mm. Width 1.71 mm.

Description. A rather eroded, ovate left sacculith. Dorsal rim somewhat broken away but probably short, rounded and continuous with the short, rounded posterior rim; ventral rim deeply rounded; anterior rim straight, vertical. Outer face smooth, slightly convex. Inner face flat, with a horizontal sulcus set a little above the mid-line, opening narrowly on the anterior rim and terminating near the postero-ventral rim. Sulcus rather indistinct but appears to consist of a short, relatively wide ostium and a narrow, horizontal cauda. A slight rounded lower angle and a moderate rounded upper angle are present at the junction of ostium and cauda while the crista superior is accentuated by a shallow depression above it. No rostrum, excisura or collicula, but there appears to be a slight antirostrum. A deep, smooth lower area is present.

This otolith has the general shape of those seen in the Monocentridae, especially that seen in *Cleidopus* De Vis, but there is also a possible affinity with *Antigonia* Lowe and

perhaps this may represent an intermediate form between these two genera. Certainly the otoliths of *Antigonia* exhibit marked berycoid characteristics and it is probable that this fish should be included within the order Berycoidei. No skeletal remains identified as berycoids have been recorded from Jurassic strata.

? Utriculith

Text-fig. 14a, b

Material. BM P48700. Bradford on Avon.

Dimensions. Length 2.18 mm. Width 1.49 mm.

An indeterminate utriculith which is rather oval and biconvex. The absence of distinguishing features makes its identification impossible.

CONCLUSIONS

The very numerous otoliths in these strata indicate a much larger fish population than the skeletal remains suggest. It is probable that littoral conditions prevailed but of moderate depth in view of the colonization of many of the specimens by serpulids and bryozoans.

Fishes and their otoliths derived from the underlying Liassic and superimposed Oxford and Kimmeridge Clays appear to be generically similar but the Bathonian specimens are specifically distinct and neither do they conform to the numerous species described by Neth and Weiler (1953, pp. 114–21), Martin and Weiler (1954, pp. 119–92; 1957, pp. 211–49) and Schröder (1956, pp. 128–53) from partly synchronous German strata. This may result from ecological differences in the various areas concerned when these beds were deposited.

The otoliths of the Jurassic fishes suggest that they are intermediary between the ganoids of the Trias and the teleosts of the Tertiary. Typically teleost features are seen in them and at least three potential groups ancestral to the modern true fishes can be demonstrated despite the absence of supporting evidence from Cretaceous strata. This latter fact may result from two causes, the Wealden fishes being ecologically different in that they were brackish or fluviatile forms and the absence of otoliths in the Chalk through their chemical composition. Otoliths do occur in the Gault but appear to be uncommon and those seen by the author were all referable to the albulid-pterothrissid lineage, a group not yet recognized in the Mesozoic. However, this may again result from an unsuitable environment during the deposition of the British Jurassic strata rather than that they had not evolved at this time.

Certainly the conflicting interpretations of the available osteological materials indicate the need for further data to resolve these problems and the otoliths offer suitable confirmatory evidence. Undoubtedly these support the views of Gosline (1960), in his definition of the limits of the Clupeiformes.

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F. C. STINTON
51 Craigmoor Avenue,
Stonden Park
Bournemouth
Hampshire
H. C. TORRENS
Department of Geology
The University
Leicester